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Short communication

Threshold temperature and cumulative energy requirement for the development of cutworm, *Agrotis ipsilon* Hufnagel

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Cutworms are polyphagous and cosmopolitan pests attacking large number of crops worldwide including India (Napiorkowska and Gawowska, 2004). The larvae usually hide in cracks and crevices in the soil or under the clods or debris around the plants during day time, and come out of these places of hiding at night and cut the young plants at ground level and feed on them (Pathania, 2010). The economically important cutworms are generally noctuids belonging to genera *Agrotis*, *Euxoa*, *Discestra* and *Peridroma*. Several species of *Agrotis* are major pests of potato in many parts of the world including North-West Himalaya (Anonymous, 2011). Temperature is one of the most important environmental factors influencing strongly the growth and many other life history traits of insects (Steigenga & Fischer, 2009). Thus, their thermal requirements and developmental rates at different temperatures are of critical importance for determining the environmental conditions that are necessary for insects to become pests (Bahar *et al*., 2012). In addition, understanding the physiological relationship between temperature and development rate is important in the prediction of population outbreaks and timely management of pests on crops (Van der Have, 2008, Nebapure *et al*., 2018). These values further can be used in predicting an accurate forecast of insect development and emergence that is important for effective pest management as studied against various pest species (Jakubowska *et al*., 2012, Duraimuruga, 2018). The present study was focused to estimate the lower developmental thresholds and degree-day requirements for *A. ipsilon* to predict its emergence time and outbreak.

The experiment was conducted from July 2018 to May 2019. The cultures of *A. ipsilon* were maintained under controlled conditions at 25 ± 1°C temperature and 75 ± 5 per cent relative humidity under 16:8 (L:D) photoperiod in Entomological Laboratory at CSK HPKV, Palampur for further studies.

Degree-day and threshold temperature

The development of *A. ipsilon* was studied at constant temperature regimes of 17.5, 20.0, 22.5, 25.0 and 27.5 ± 0.5 ˚C in BOD incubator with relative humidity varying between 55 to 75% and 12:12 (L:D) photoperiod. One hundred eggs were placed in each temperature regime and percentage hatch was recorded. The newly emerged larvae were placed individually on fresh tender leaves of cabbage in plastic jars (5x6 cm) and duration of development was recorded for an individual in a particular instar. The larval developmental threshold temperature was established on the basis of the rate of development observed among different growth stages when reared under each temperature regimes. The threshold temperature (t) was calculated for egg, larva, pre-pupa and pupa based on a linear model. Data obtained from the experiments were described by the linear regression equation of $Y = a + bX$, where Y is the rate of development at temperature X, and *a* and *b* are constants that were estimated with the least squares method described by Campbell *et al*. (1974) and Beck (1983). The developmental threshold thus estimated may then be used as the basis for predicting developmental rates and thermal unit accumulations, based on the equation:

$$K = b\ (T-t)$$

Where,

K is the rate of development (the reciprocal of the time period required to complete a given development stage at temperature T; b is a constant (the slope of linear regression); and t is the estimated developmental threshold temperature [t= T- (K/b)] or –a/b, while the thermal constant (K) expressed in degree days (DD) was estimated as K = 1/b. The cumulative degree-day (DD) requirement to complete

Table 1: Duration of developmental stage of *A. ipsilon* at different temperature

Temperature regimes (˚C)	Mean duration (Days)			
	Egg	Larva	Pre-pupa	Pupa
17.5	8.4	49.8	4.5	28.2
20.0	5.4	35.5	3.15	21.6
22.5	4.3	30.7	2.7	17.3
25.0	3.5	24.2	2.3	15.0
27.5	3.0	19.8	1.8	12.85

Table 2: Survival of *A. ipsilon* life stages at five constant temperatures

Temperature (˚C)	Survival in each stage (%) *				Total (Egg-Adult emergence)
	Egg	Larva	Pre-pupa	Pupa	
17.5	95.0	55.8	84.9	84.4	38.0
20.0	95.0	88.4	89.3	89.3	67.0
22.5	90.0	76.7	88.4	95.1	58.0
25.0	92.0	76.1	88.6	85.5	53.0
27.5	94.0	68.1	92.2	86.4	51.0

*Survival expressed as per cent of total at the beginning of each stage.

the developmental stage was calculated by equation:

DD= (T-t)/K

The number of individual survivals at the end of each developmental stage under different temperature was recorded in order to calculate the survival percentage of each stage.

Degree-day/energy and threshold models are essential prerequisite for successful management of *A. ipsilon*. The information on the development threshold is used as the basis for calculating thermal unit accumulation (degree-day) which in turn is useful in predicting field occurrence and development of the pest. Such predictive degree- day models also provide valuable information for developing control programmes.

Developmental rate and survival of different stages

The rate of development of different stage of *A. ipsilon* at five constant temperature regimes of 17.5, 20.0, 22.5, 25.0 and 27.5 ˚C was studied. The incubation period decreased with increase in temperature and took 8.4, 5.4, 4.3, 3.5 and 3.0 days, respectively. The larval development was completed in 49.8, 35.5, 30.7, 24.2 and 19.8 day at the respective temperature. At 17.5 ˚C, the duration of pre-pupa and pupa was 4.5 and 28.2 days. Whereas, at 27.5˚C, it was 1.8 and 12.8 days, respectively. The total development period from egg to adult emergence was completed in 91.3, 65.7, 55.7, 45.6 and 36.7 days at 17.5, 20.0, 22.5, 25.0 and 27.5 ˚C, respectively (Table 1). The percent survival of life stages of *A. ipsilon* in response to temperature regimes are presented in Table 2. The egg hatchability was not much influenced by the temperature which ranged between 90-95%. The larval survival was maximum (88.4%) at 20.0 ˚C followed by 76.7% at 22.5˚C and 76.1% at 25.0˚C. The minimum survival (55.8%) was recorded at 17.5˚C. The pupa survival varied between 85.5 to 95.1% at the tested temperature regimes. The survival of the complete development from egg to adult emergence was minimum (38.0%) at 17.5˚C and maximum (67.0%) at 20.0˚C.

Threshold temperature and energy/degree-days (DD)

The lower development threshold temperature calculated from the linear regression equation was 11.58, 10.83, 10.38, 8.99 and 10.64˚C for egg, larva, pre-pupa, pupa and total life cycle, respectively (Table 3). The number of degree-day (DD) calculated from the lower developmental threshold for each life stage (Table 4), revealed that an average of 47.4, 337.8, 31.9 and 237.9 DD were required for completion of egg, larval, pre-pupa and pupal development, respectively. A total of 635.3 DD was required for completing development from egg to adult stage. Beck (1986) reported the lower developmental threshold of 11˚C for the 2nd instar, 9.1˚C for 6th instar and 8.27˚C for pupa, slightly lower than that estimated for larva and pupa in the present study. The threshold temperatures estimated in the present study disagree with those of Olufade (1972) who reported the lower threshold for egg, larva and pupa as 9.9, 8.8 and 10.5˚C, respectively. The estimated required for egg was 61.1 DD. The lower degree-day requirement calculated in this study is due to greater threshold value for the egg, estimated in

Table 3: Lower developmental threshold temperature of different life stages of *A. ipsilon*

Temperature (˚C)	Calculated threshold temperature (˚C)				Total (Egg-Adult emergence)
	Egg	Larva	Pre-pupa	Pupa	
17.5	11.8	10.72	10.41	9.06	10.54
20.0	11.25	10.48	9.88	8.99	10.33
22.5	11.51	11.50	10.69	8.75	11.09
25.0	11.50	11.04	11.14	9.14	11.06
27.5	11.75	10.43	9.78	8.99	10.18
Mean	11.58	10.83	10.38	8.99	10.64
C. D. at 5%	0.22	0.44	0.57	0.15	0.42
S. Em. ±	0.10	0.20	0.25	0.07	0.19
δ (Slope)	0.0212	0.0030	0.0314	0.0042	0.0016

Table 4: Degree-day/energy estimate for different life stages of *A. ipsilon*

Temperature (˚C)	Degree-day/energy estimates				Total (Egg-Adult emergence)
	Egg	Larva	Pre-pupa	Pupa	
17.5	49.7	332.2	32.0	240.0	626.6
20.0	45.5	325.5	30.3	237.8	615.4
22.5	47.0	358.3	32.7	233.7	661.0
25.0	47.0	342.9	33.6	240.2	654.8
27.5	47.8	330.1	30.8	237.9	618.8
Mean	47.4	337.8	31.9	237.9	635.3
C. D. at 5%	1.5	13.1	1.4	2.6	21.1
S. Em. ±	0.61	5.25	0.54	1.04	8.45

this study than reported by earlier workers. The degree-day required for the larval development as reported by these workers varies from 356- 387.3 DD; which is higher than that estimated in the present study. Possibly the pre-pupal stage has been also included in the larval stage while calculating DD requirements. A total of 635.3 DD was required for completing development from egg to adult stage in present study. Dahi *et al*. (2009) reported that the time required for development was decreased as the temperature increased from 20 to 30 °C. The lower threshold temperatures (t) were 11.49 °C for eggs, 10.63 °C for larvae, 9.83°C for pupae, 11.06 °C for pre-oviposition period and 10.53 °C for generation. The average thermal requirements needed for completing the development were 51.3, 303.5, 183.5, 38.1 and 575.3 degree-days for eggs, larvae, pupae, pre-oviposition period and generation, respectively.

Study indicates that the duration stages *viz.,* incubation period, larval, pre-pupa, pupa and total development period decreased with increase in temperature. Thus, in the present scenario of climate change, the estimation of degree day allows us in predicting the emergence time of a particular life stage of insect pest that causes the damage to optimize the timing of population monitoring and control strategies.

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